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ABSTRACT

This study focuses on the impact of scientific writing resulting from an inquiry-based instructional approach on students' critical thinking. Students are encouraged in being actively involved in the process of science, by using the Science Writing Heuristic (SWH; Hand and Keys, 1999). The SWH consists of a framework to guide students' science activities as well as a support to prompt students' reasoning about data while writing. Further, the SWH provides teachers with a template of suggested strategies to enhance learning from laboratory activities. As a whole, the SWH seeks to provide authentic meaning- making opportunities for learners. (Author)

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The impact of a scientific writing approach in high school students' learning

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Introduction

This study focuses on the impact of scientific writing resulting from an inquiry-based instructional approach on students' critical thinking. Students are encouraged in being actively involved in the process of science, by using the Science Writing Heuristic (SWH; Hand and Keys, 1999). The SWH consists of a framework to guide students' science activities as well as a support to prompt students' reasoning about data while writing (template 1). Further, the SWH provides teachers with a template of suggested strategies to enhance learning from laboratory activities (template 2, not discussed here). As a whole, the SWH seeks to provide authentic meaning-making opportunities for learners.

The SWH links individually-constructed science understandings, with canonical forms of reasoning in science through the negotiation of meaning using oratorical and analytic formats of argumentation (Duschel et al., 2002). The students' template prompts them to generate questions, claims, and provide evidence for their claims. When students state a claim for an investigation, they are expected to describe a pattern, make a generalization, state a relationship, or construct an explanation. It also prompts learners to compare their laboratory findings with others, including their peers and textbooks (or other sources), and to reflect on how their own ideas have changed during the laboratory activity. In this way the heuristic scaffolds learners in both, individual understanding of the science activity and connecting this knowledge to other scientific ideas. The SWH is designed to promote classroom discussion in which students' individual explanations and observations are tested against the contributions of the broader group. Learners are encouraged to make explicit and defensible connections between questions, observations, data, claims, and evidence.

The written document that results from the implementation of the SWH constitutes an alternative format for a laboratory report; based on the assumption that science writing in school should reflect some of the characteristics of scientists' thinking and writing. In this study we explore the impact of the SWH in students' cognitive activities through text analysis of laboratory reports of low, middle and high achievers. From the cognitive analysis of the texts we expect to answer the following questions:

1. Are the patterns of cognition, in terms of developing evidence to support claims, the same across the diverse achieving groups?
2. Is using the SWH beneficial for low achieving students? If so, how?
3. How the different nature of laboratory activity affects the students' cognitive actions of diverse achieving groups?

Experimental Design

This study was conducted on Year 10 Advanced Biology class, using a quasi-experimental design with a pre-posttest format. This research included a control group, in which students received a teacher-centered instruction, and a treatment group, in which a science unit was approached using the SWH instruction. Within each group high, middle,

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and low achievers students were identified based on the average of a baseline chemistry test prior to the instruction, and the Advance Biology semester grade. High and low achievers represent the upper and lower 20% of the class average grades, respectively. Middle achievers represent the 20% of the remaining group and were chosen randomly. Each achieving subgroup in control and treatment groups, contains four students.

The participating teacher chose a unit of study in Biology, the cell, including at least three laboratory activities of different nature. The activities analyzed here are the following: 1) observational, in which students observed a cell sample under the microscope, 2) modeling, in which the cell membrane and its functions were simulated with a plastic bag, and 3) inferential, in which the students were required to explain the process of diffusion as a function of different variables. The time on task for control and treatment groups was equivalent, and had the same type of laboratory activities.

Cognitive analysis

The analysis of students' writing aimed to uncover the cognitive paths that students undergo through writing a laboratory activity report. The analysis is based on cognitive categories that emerged from students' documents. The categories were defined following the study on critical thinking by Ennis (1985); while the criteria used for their ordination in a complexity scale were based on the number of domains (or dimensions) implied by the cognitive category (Halford and McCreden, 1998), the number of relations between domains, and the nature of both domains and relations. In what follows are included the ordered list of cognitive categories along with their definitions as were used in the cognitive coding.

Table 1. Cognitive Categories

Cognitive Categories	Definition
Formal categories	
1. Observation	Data that result from students' observations
2. Measurement	Reference to any quantitative aspect of the data
3. Compare/similarity	Reference to common characteristics of two or more pieces of data or objects
4. Compare/contrast	Reference to different characteristics of two or more pieces of data or objects
5. Analogy	Mapping elements from a source domain (well understood situation) into a target domain (non-familiar situation).
6. Clarification/question	Questions that stimulates conceptual clarification or challenges
7. Clarification/argument	Facts used to support other cognitive actions
8. Claim	Unproved inference or explanation.
9. Inference/causal	Identification of a cause and its effect

10. Induction/generalization	Reasoning that links few examples to general premises
11. Deduction/logic	Reasoning that links general premises to a specific.
12. Investigation/design	Planning new experiments
Dialogical categories	
13. Negotiation/authority	Argumentation with authority, including the teacher, books, or other sources
14. Negotiation/peers	Argumentation with peers.

Implications of high order cognitive categories in science learning

High order cognitive categories are conceptions, which relate elements belonging to different domains. The first two categories, observations and measurements, refer to one domain based on a unitary relation (Halford and McCreede, 1998), while comparisons by similarity or contrast include two arguments that belong to the same domain. A justification of the degree of complexity assigned to other cognitive categories is discussed below. These categories fulfill the requirements of inquiry as outlined in the National Science Education Standards (NRC, 1996).

Analogy
Analogy is a complex conceptual task that relates two different domains, the source and the target. The relationship between domains is a comparison based on structural, functional, or causal similarities. The positive impact of the use of analogies was identified in diverse areas of science learning such as problem solving (Friedel et al., 1990), conceptual understanding of scientific content (Genter and Genter, 1983; Joshua and Dupin, 1987), and construction of scientific explanations and ideas (Nersessian, 1992; Wong, 1993; Baker and Lawson, 2001). In general, analogies contribute to conceptual change making new concepts intelligible (Dupin and Joshua, 1989). Analogies not only enhances the conceptual understanding aspect of learning, but also has a contribution to psychological learning factors, providing students comfort and security through he connection of their own world with the world of abstractions (Dagher, 1994).

Questioning
It is a complex conceptual task that relates the domains of what students' know (K) with what is desired to know (DK). The domains overlap, and questioning result from the exclusion of K from DK. Students' formulation of research questions monitors students' comprehension of a topic; it stimulates a self-reflection on students' knowledge and states a starting point for the instruction (Halpern, 1990). Also, students' questioning contributes to develop a sense of ownership of the inquiry process contributing to positive emotive learning factors (Grimberg and Hand, in preparation).

Claims

Claims are tentative explanations to observations and measurements. Claims constitute a complex conceptual task because relates two conceptual domains: the physical domain of observations and measurements, with the formal domain of theories and explanations. However, at this tentative stage the relation between both domains is not well defined. Claims are characteristic of scientific practice and discourse, therefore students' formulations of claims not only stimulates high order thinking but also involves students in the scientific discourse. The participation in the discursive form of a discipline is a crucial aspect in learning that discipline (Greeno, 1990).

Inference/causal

It is a complex conceptual task because establishes a causal relation between two domains: cause and effect. In general, both domains are not simultaneously identified *a priori*, either the effect is known and the cause should be the determined or *vice versa*. A causal relationship implies a sequential order between these domains.

Induction/generalization

It refers to the ability to extract regularities from experiences or examples, and their posterior generalization. The distinction of regular properties requires decision-making strategies (Luger, 1994). Inductive thinking is a complex conceptual task that relates more than two domains, including some examples (pre-inductive domains) and a generalization (inductive domain). Pre-inductive domains are related through comparisons, while relate to the generalization domain through a causal relation. Overall the number of relation is equal to number of domains minus one. Inductions allow the formulation of generalizations that lead to models. The formulation and revision of scientific models are crucial to develop scientific knowledge.

Deduction/logic

It is a complex conceptual task that relates general premises with specific examples. It involves more than two domains with a number of relations equal to the number of domains. The relations between domains could be comparison or causal. The premises that result from deduction have a predictive character.

Investigation/design

Usually this task involves a backward design, which first requires the identification of desired results, then the specification of acceptable evidence, and at last the planning of the investigation. This task is complex because is necessary the integration of the cognitive activities discussed above, such as: clarification question, claims, inference/generalization, or and deduction logic. It involved

Negotiations with authority and peers

It is a complex conceptual task because require the integration of previous high order conceptual tasks such posing claims and evidence that support that claim. Indeed, scientific argumentation provides learners with a model in which the relation between claim and evidence is explicit. Negotiations with authority focus mostly on "information" while negotiations with peers, taking place in small group interactions,

focus mostly on "doing" (Omar et al., in preparation). There is strong evidence that students' involvement in scientific forms of communication and argumentation improve science learning (Duschl and Ellenbogen 2002; Osborne et al., 2002; Herrenkhol et al., 1999; Shauble et al., 1995).

Preliminary results on students' cognitive dynamic

In order to determine the impact of the SWH in students' cognitive dynamics (here dynamics refers to the cognitive activities and their sequence in time) we compared the cognitive analysis that resulted from laboratory reports of students that received a teacher-centered instruction with those resulting from SWH instruction. The effect of inquiry-based instruction on students' achievement levels was also considered by comparing the cognitive dynamics of low, middle, and high achieving students within each group. The comparison between control and treatment cognitive dynamics was replicated across three different laboratory activities within a unit topic.

Cognitive dynamics derived from students' writings that resulted from teacher-centered instruction and SWH are shown in Figures 1, 2, and 3. The vertical axis contains the complexity scale (from 1 to 14) corresponding to the cognitive categories specified in Table 1. The horizontal axis contains the counting of cognitive codes (or entries) registered in each text in a sequential manner. The solid/diamond, solid/square, and solid/triangle lines correspond to the cognitive dynamics of a high, middle and low achieving student, respectively.

The cognitive dynamics corresponding to control students' documents, mostly display the first five cognitive categories of Table 1, while students' writings resulting from the SWH instruction are characterized by higher order cognitive categories, including students' own questions (see the graphs of control and treatment groups in Figure 1, 2, and 3, respectively). Another difference between control and treatment writings is students' spontaneous use of the cognitive categories. The cognitive categories displayed in control documents were mostly indicated by the teacher (through questions that required comparisons, etc…). In particular for the observational and modeling activities, students conducted their laboratory by answering a questionnaire including recall and "fill in the blank" questions. Only for the inferential activity the students wrote a traditional laboratory report, including predictions, materials, procedure, results, and conclusions. The cognitive dynamics resulting from inquiry-based instruction documents were rich in high order cognitive categories, the use of inferences, induction, and deduction were facilitated by the instruction but not explicitly required. Students naturally tend to engage in higher order thinking if the learning environment allows it.

The distributions of codes through the cognitive categories for the three laboratory activities, of control and treatment groups, are shown in the histograms of Figures 4, 5, and 6. Gray, black, and white bars represent high, middle, and low achieving students distributions. The horizontal axis contains the complexity scale (from 1 to 14)

corresponding to the cognitive categories, while the vertical axis contains the number of codes in each category.

The trends found in individual cognitive dynamics are reinforced by the code distributions of the achievement subgroups. Histograms corresponding to the SWH subgroups display more entries for the three laboratory activities than those of the control group. Also, the treatment histograms are rich on high order cognitive categories such as questioning, claims, inference/causal, and negotiations for low, middle, and high achievers. It is notable the relation in the number of high order codes for middle and high achievers in the SWH histograms. For these histograms, middle achievers display a number of cognitive activities comparable (or higher in some cases) to the high achievers. The code distributions of low achievers in the treatment group indicate an increment in the number of high order cognitive categories with respect to the categories displayed by the control group, but still lagging high achieving students' cognitive dynamics.

The most used cognitive categories by high, middle and low achieving students as shown in the SWH histograms for the three laboratory activities, are observations (category 1), questioning (6), claims (8), and negotiations (13 and 14). In particular, the inferential activity prompted the use of cause/effect relations (9). From these reduced sample histograms we cannot see any selective use of cognitive categories for different laboratory activities regarding the achievement level of the students.

Conclusions

The conclusions obtained from the present study should be treated as preliminary, due to the reduced sample in each achievement subgroup for control and treatment groups. However individual cognitive dynamics and collective codes distributions, indicate the following trends:

1) SWH stimulates high order cognitive actions, as opposed to teacher-centered approach in which students are not cognitive engaged in high order categories.

2) SWH scaffolds high order thinking. In particular, the impact on low achieving students could results in closing the gap between low and high achievers' cognitive dynamics.

3) Cognitive actions depend on the nature of the activity, inferential activities prompted high order categories.
4) There is no indication that students with different achievement levels perform different cognitive actions for a specific laboratory activity.

Further work including larger students samples across grades and disciplines is under way.

References

Baker, W. P., & Lawson, A. E. (2001). Complex instructional analogies and theoretical concept acquisition in college genetics. *Science Education, 85*, 665-683.

Dagher Z. R. (1994). Does the use of analogies contribute to conceptual change? *Science Education, 78*, 601-614.

Dupin, J., & Joshua S. (1989). Analogies and "modeling analogies" in teaching: Some examples in basic electricity. *Science Education, 73*, 207-224.

Duschl, R. A., & Ellenbogen K. (2002). *Argumentation Processes in Science learning*. Paper presented at the Ontological, Epistemological, Linguistic and Pedagogical Considerations of Language and Science Literacy: Empowering Research and Informing Instruction. British Columbia, Canada.

Ennis, R. H. (1985). Goals for a Critical Thinking Curriculum. In Arthur L. Costa (Ed.), *Developing Minds: A Resource Book for Teaching Thinking*. ASCD publications.Friedel , A., Gabel, D., & Samuel, J. (1990). Using analogies for chemistry problem solving. *School Science and Mathematics, 90*, 674-682.

Gentner, D., & Gentner, D. R. (1983). Flowing water or teeming crowds: mental models of electricity. In D. Gentner and L. Stevens (Edts.), *Mental Models*. Hillsdale, NJ: Lawrence Erlbaum Assoc., Inc.

Glaser R. (1990). Expert knowledge and the process of thinking. In Diane F. Halpern (Edt.), *Enhancing Thinking Skills in the Sciences and Mathematics*. Hillsdale, NJ: Lawrence Erlbaum Assoc., Inc.

Greeno J. G. (1990). Mathematics and scientific thinking in classrooms and other situations. In Diane F. Halpern (Edt.), *Enhancing Thinking Skills in the Sciences and Mathematics*. Hillsdale, NJ: Lawrence Erlbaum Assoc., Inc.

Halford, G. S., & McCreeden, J. E. (1998) Cognitive Science questions for cognitive development: the concepts of learning, analogy, and capacity. *Learning and Instruction, 8,* 289-308.

Halpern D. F. (1990). A cognitive approach to improving thinking skills in the sciences and mathematics. In Diane F. Halpern (Edt.), *Enhancing Thinking Skills in the Sciences and Mathematics*. Hillsdale, NJ: Lawrence Erlbaum Assoc., Inc.

Herrenkohl, L., Palincsar, A., DeWaters, L., & Kawasaki, K. (1999). Developing scientific communities in classrooms: A sociocognitive approach. *Journal of the Learning Sciences, 36,* 1085-1109.

Joshua S., & Dupin J. (1987). Taking into account student conceptions in instructional strategy: An example in physics. *Cognition and Instruction, 4*, 117-135.

Luger G. F. (1994). *Cognitive Science*. San Diego, CA: Academic Press.

National Science Education Standards (1996). Natl. Academy Press, Washington DC.

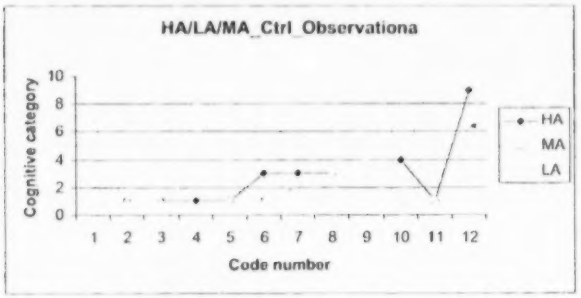
Nersessian, N. (1992). Constructing and instructing: The role of "abstraction techniques" in creating and learning physics. In R. Duschl & R. Hamilton (Eds.) *Philosophy of science, cognitive psychology, and educational theory and practice*. Albany, NY: State University of New York Press.

Osborne, J., Simon, S., & Enduran, S. (2002). *Enhancing the quality of argumentation in school science*. Paper presented at the Ontological, Epistemological, Linguistic and Pedagogical Considerations of Language and Science Literacy: Empowering Research and Informing Instruction. British Columbia, Canada.

Schauble. L., Glaser R., Duschl, R., Schulze, S., & John, J. (1995). Students' understanding of the objectives and procedures of experimentation in the science classroom. *Journal of the Learning Sciences*, 4, 131-166.

Wong, E. D. (1993). Self-generated analogies as a tool for constructing and evaluating explanations of scientific phenomena. *Journal of Research in Science Teaching, 30*, 367-380.

Figure 1. **Cognitive dynamics: Observational activity**



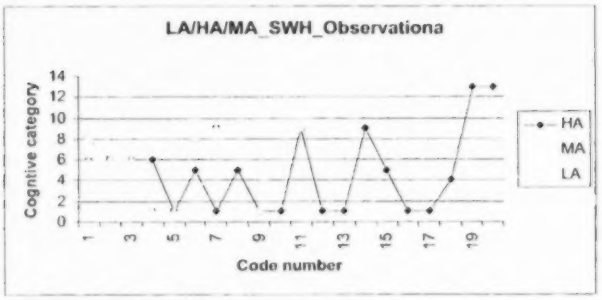
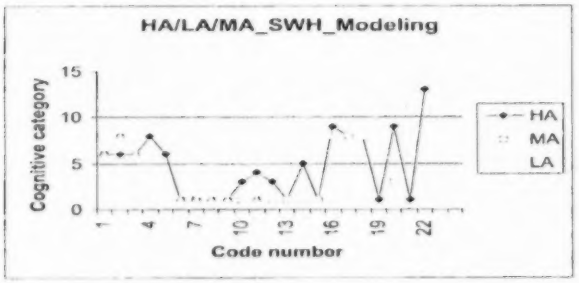


Figure 2. **Cognitive dynamics: Modeling activity**



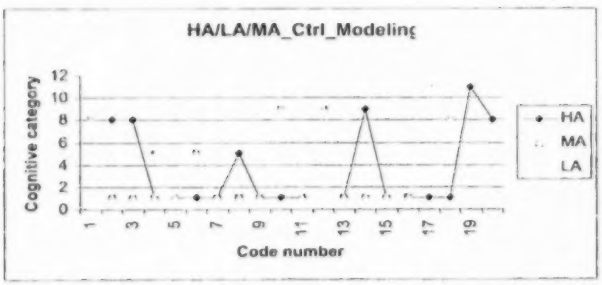
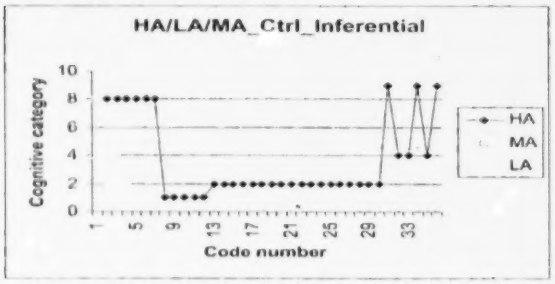


Figure 3. **Cognitive dynamics: Inferential activity**



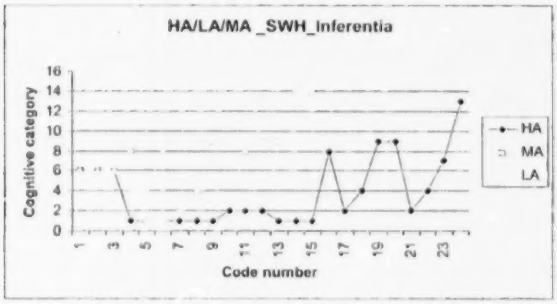
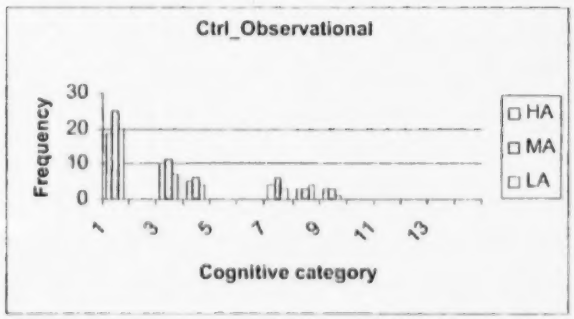


Figure 4. **Codes distribution: Observational activity**



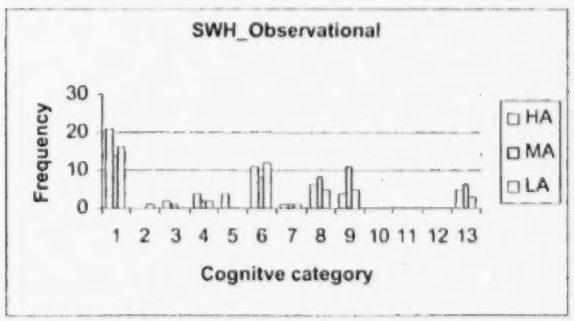
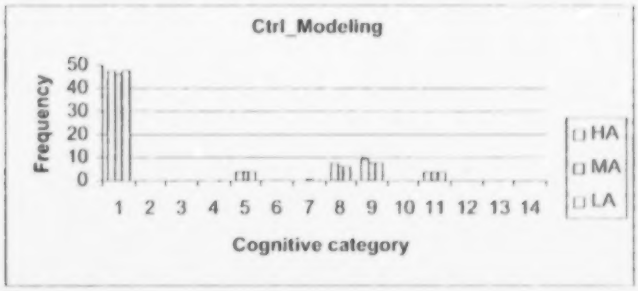


Figure 5. **Codes distribution: Modeling activity**



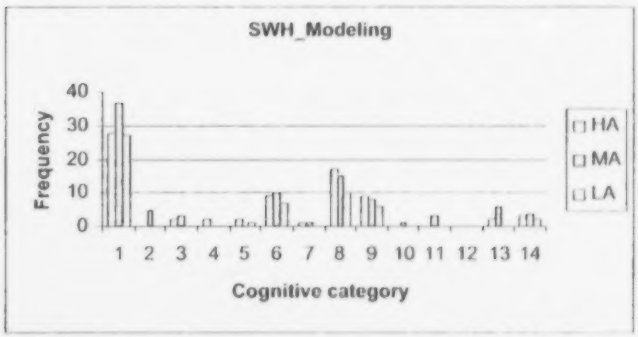
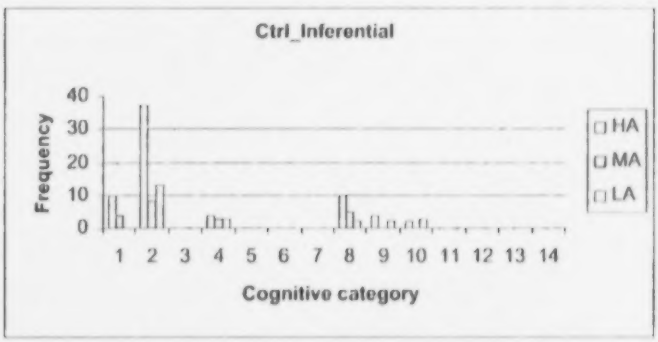
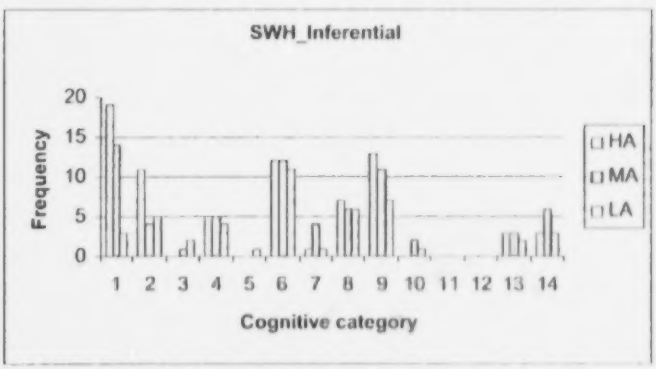


Figure 6. **Codes distribution: Inferential activity**





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